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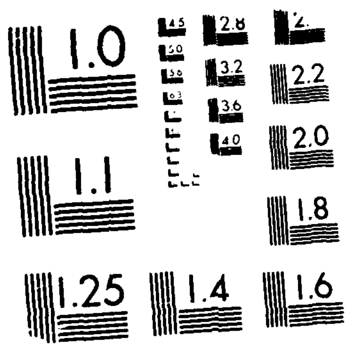

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Shipboard systems, subsystems, and equipments are not designed to optimize overall operational performance or mission effectiveness. The problem manifests itself through system level under utilization of potential warfighting capability and operational performance inherent in the highly capable subsystem and equipment components.

This is considered attributable to the fact that our shipboard crews do not operate, test, train on, or assess performance of well defined systems, subsystems, and components with carefully integrated operator surveillance and control functions that enhance system level operator decision making and response actions. Rather they tend to employ an aggregation of equipments and component tests and training to perform a subfunction and it is up to the operators to assess performance and determine the operational interaction of components. The operational use of the "system" and assessment of responses to sensor inputs are relegated to training and all too often it is training or the operator himself, rather than control system design that is considered at fault when the system or operators are incapable of coping with an operational situation.

The integration of test, training, and performance assessment requirements into control and surveillance system design has become a necessity due to escalating complexity, costs of duplicative and redundant design, equipment, software and the pressing need to provide for real time utilization of full total ship capabilitiy.

The integrated, distributed control and surveillance systems of today provide the baseline for total system level test, training, and performance assessment as well as the intrinsic system level capability to meet operational performance requirements if included in preliminary design.

This paper discusses recent developments in overlapping requirements, system design, functional allocation, and operational implementation of Integrated Test, Training, and Performance Assessment utilizing a distributed microprocessor control and surveillance system design.

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19. ABSTRACT Continued.

Modern computer/microprocessor based control and surveillance systems have evolved into two basic shipboard "systems";

the "combat system" comprised of radars, sonar, electronic warfare suites, and associated control processors, and

the "engineering control system" comprised of auxiliary, electrical, propulsion, damage control, steering, and associated central control station processors.

Within the next ten years, these two separate, yet interdependent "systems" are expected to be combined over a common data bus into one shipboard control system. Yet the overall control systems of today have been designed and procured by accumulating and interfacing the equipments and subsystem components with little understanding of how the total system will function under various operating conditions, workloads and degrees of casualties or battle damage. Further, the typical system procurement is based on long used, and often outdated, standards and specifications defined for stand-alone equipments or subsystems of the 1950-1970's. The result has been that new control systems have been fielded with obsolescent system level control because of the inability to determine how the introduction of new or evolving technology will cross the procurement interface and affect the total system under development. Unlike modern data networks that have system integrity features to enable network users to determine that the network is passing data, the individual systems with the built-in-test (BIT) and training features are not designed to perform in a team environment.

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REPRODUCED AT GOVERNMENT EXPENSE

INTEGRATION OF TEST, TRAINING, AND PERFORMANCE ASSESSMENT INTO DISTRIBUTED CONTROL AND SURVEILLANCE SYSTEM DESIGN

by

John G. Kammerer, Naval Ocean Systems Center
David W. Geer, Martin Marietta Baltimore Aerospace
Thomas R. Tiernan, Naval Ocean Systems Center

ABSTRACT

Shipboard systems, subsystems, and equipments are not designed to optimize overall operational performance or mission effectiveness. The problem manifests itself through system level under utilization of potential warfighting capability and operational performance inherent in the highly capable sub-system and equipment components.

This is considered attributable to the fact that our shipboard crews do not operate, test, train on, or assess performance of well defined systems, subsystems, and components with carefully integrated operator surveillance and control functions that enhance system level operator decision making and response actions. Rather they tend to employ an aggregation of equipments and component tests and training to perform a sub function and it is up to the operators to assess performance and determine the operational interaction of components. The operational use of the "system" and assessment of responses to sensor inputs are relegated to training and all too often it is training or the operator himself, rather than control system design that is considered at fault when the system or operators are incapable of coping with an operational situation.

The integration of test, training, and performance assessment requirements into control and surveillance system design has become a necessity due to escalating complexity, costs of duplicative and redundant design, equipment, software and the pressing need to provide for real time utilization of full total ship capability.

The integrated, distributed control and surveillance systems of today provide the baseline for total system level test, training, and performance assessment as well as the intrinsic system level capability to meet operational performance requirements if included in preliminary design.

This paper discusses recent developments in overlapping requirements, system design, functional allocation, and operational implementation of Integrated Test, Training, and Performance Assessment utilizing a distributed microprocessor control and surveillance system design.

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INTRODUCTION

Modern computer / microprocessor based control and surveillance systems have evolved into two basic shipboard "systems";

> the "combat system" comprised of radars, sonar, electronic warfare suites, and associated control processors, and
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> the "engineering control system" comprised of auxiliary, electrical, propulsion, damage control, steering, and associated central control station processors.

Within the next ten years, these two separate, yet interdependent "systems" are expected to be combined over a common data bus into one shipboard control system. Yet the overall control systems of today have been designed and procured by accumulating and interfacing the equipments and subsystem components with little understanding of how the total system will function under various operating conditions, workloads and degrees of casualties or battle damage. Further, the typical system procurement is based on long used, and often out dated, standards and specifications defined for stand-alone equipments or subsystems of the 1950-1970's. The result has been that new control systems have been fielded with obsolescent system level control because of the inability to determine how the introduction of new or evolving technology will cross the procurement interface and affect the total system under development. Unlike modern data networks that have system integrity features to enable network users to determine that the network is passing data, the individual systems with their built--in-test (BIT) and training features are not designed to perform in a team environment.

TEST

Determining overall equipment and computer program operability through test procedures is typically an aggregation of equipment and subsystem test results together with interface tests. The test process generally parallels the equipment / subsystem design and procurement process as well as the designed operational control and display features. This process does not fully test the total system tactical / operational software on which the operability of the total system depends. While manual overall system level tests are performed today at the combat system level they are very slow and limited in scope. Additionally the manual overall combat system process and the aggregation process does not assess the impact of degraded performance of the equipment and computer programs and provide that information to the decision makers and repair technicians in a timely manner in a usable format.

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TRAINING

In addition to equipment and computer program considerations, shipboard system designs specifically includes the human operator as part of the operational design philosophy. Thus, the operators timely and correct response to stimuli is essential to system performance. Realistic total system training time, underway or inport, is minimal. The attrition of operator and team skills without continuous training on the systems is such that it declines to the point that even if the mechanical and electrical components are operable, the overall system performance is below design capability. Just as important to training the operators and decision makers, is training them realistically and recognizing the shortcomings of their abilities, the shortcomings of their equipments and computer programs, and learning how to cope with the conditions at hand. Constant and continuing practice and assessment of the individuals, subteams, and the ship as a team entity becomes vitally important for ship safety in peacetime and survival in battle.

PERFORMANCE ASSESSMENT

In an active sense, where the input is controlled, performance assessment is a comparison of the actual output to an expected output or standard.

Performance assessment can also be passively accomplished. In this case, performance assessment is more of a surveillance or monitoring function. For example, the Combat Information Center Watch Officer and Engineering Officer of the Watch perform passive performance assessment functions.

Whether active or passive, performance assessment is a surveillance of the systems vital signs and an analysis of the impact of non-standard events on the operational capability of the system. System performance can be improved with knowledge of the systems actual state through system control design features.

INTEGRATED TEST, TRAINING, AND PERFORMANCE ASSESSMENT

To test and assess performance at the shipboard system level, a stimuli can be injected into the front end of the combat systems surveillance systems and monitored with surveillance devices and techniques through each component, equipment, sub-system. The external stimuli causes certain responses by the equipment and computer programs of the combat system which in turn causes certain responses by the equipment and computer programs of the engineering control system. This technical approach is a philosophy best described as "from the outside-in" as contrasted to the aggregation of component, equipment, and subsystem "inside-out" testing at all levels. The external STIMULATION causes the ship to be tested and assessed as one entity. The surveillance radars, sonars, electronic warfare, and intelligence suites must

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function, but they in turn are directly dependent on the engineering functions of the ship working to their designed efficiency.

As the external stimulation causes the combat system and the engineering system equipments and computer programs to react, it additionally causes the third component and perhaps the most important component of the "system", the people, to react. The stress test causes the operators to form habits, thoughts, and behavior patterns to complete the tests, operate their equipments and computer programs, and cope with the situation as the tests are run. Thus as the system is tested and the equipment and computer programs performance is assessed, it is also accomplishing training and performance assessment of the people. The functions of test, training, and performance assessment are so intertwined when front end stimulation is induced that it is logical to integrate them into one being, Integrated Test, Training, and Performance Assessment (ITT&PA).

INTEGRATED TEST, TRAINING, AND PERFORMANCE ASSESSMENT MODEL

Figure 1, respresents a model of the principles of Integrated Test, Training, and Performance Assessment (ITT&PA).

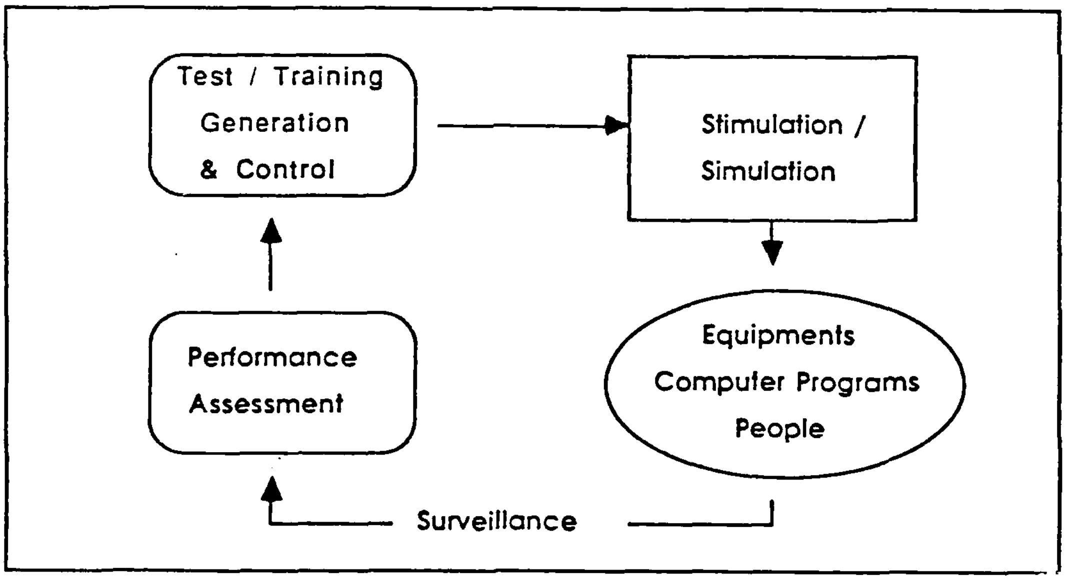

Figure 1 - Integrated Test, Training, & Performance Assessment Model

The Scenario Generation and Control function is the origin of the test to be conducted. The Scenario Generation and Control function causes the stimuli to be injected into the equipment and computer programs via stimulation / simulation techniques. Since people operate and control the equipments and computer programs they too are exercised. That is, the Scenario Generation and Control function is test control and it is training control. Surveillance devices and techniques monitor the reaction of the

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hardware, software, and people and feedback the test/training results to the control function. A comparison of the known input to the actual output versus the expected output allows the performance of the system to be determined.

COMBAT SYSTEM EXAMPLES

The AN/USQ-93 (V) Shipboard Radar Environmental Simulator System (RESS) is being built as a complement to the New Threat Upgrade Anti-Air Warfare Combat System improvement program. System design includes a Test, Training, Performance Monitoring Controller, radar and IFF stimulators, and distributed processors. The system was built for test but is used extensively for training.

The AN/SQQ-89 On Board Trainer (OBT) is being built as a sonar suite trainer but will have extreme applicability for sonar stress tests.

The Perry Class Pierside Combat System Team Trainer, Device 20B5 uses a scenario generator/controller, sensor and weapon stimulation and simulation techniques, distributed processing, and fiber optic communication connectivity to train the entire FFG-7 Class Combat System. Lessons learned indicate that even though it was built as a trainer, signficant amount of "system" tests are conducted.

The LHD-1 class ship is built with the AN/SSQ-91 (V) Combat Simulation Test System (CSTS). A test system, that like its predessor currently onboard onboard the DDG-993 class ship, will also train the combat system team. The architecture of the LHD-1 CSTS is illustrated in Figure 2.

ENGINEERING APPLICATION

As combat systems are starting to implement system level test, training, and performance assessment tools, the lessons learned become applicable to the engineering aspects of the ship. Figure 3 illustrates the concept of ITT&PA applied to the engineering requirement for test, training, and performance assessment of its "system". Although the concepts of machinery testing and performance assessment have been explored and utilized in the past, for example Test Evaluation and Monitoring System (TEAMS), Centralized Automatic Test System (CATS), and Shipboard Machinery Performance Monitoring System (SMPMS), the integration of test, training, and performance assessment for the engineering system is a relatively new concept.

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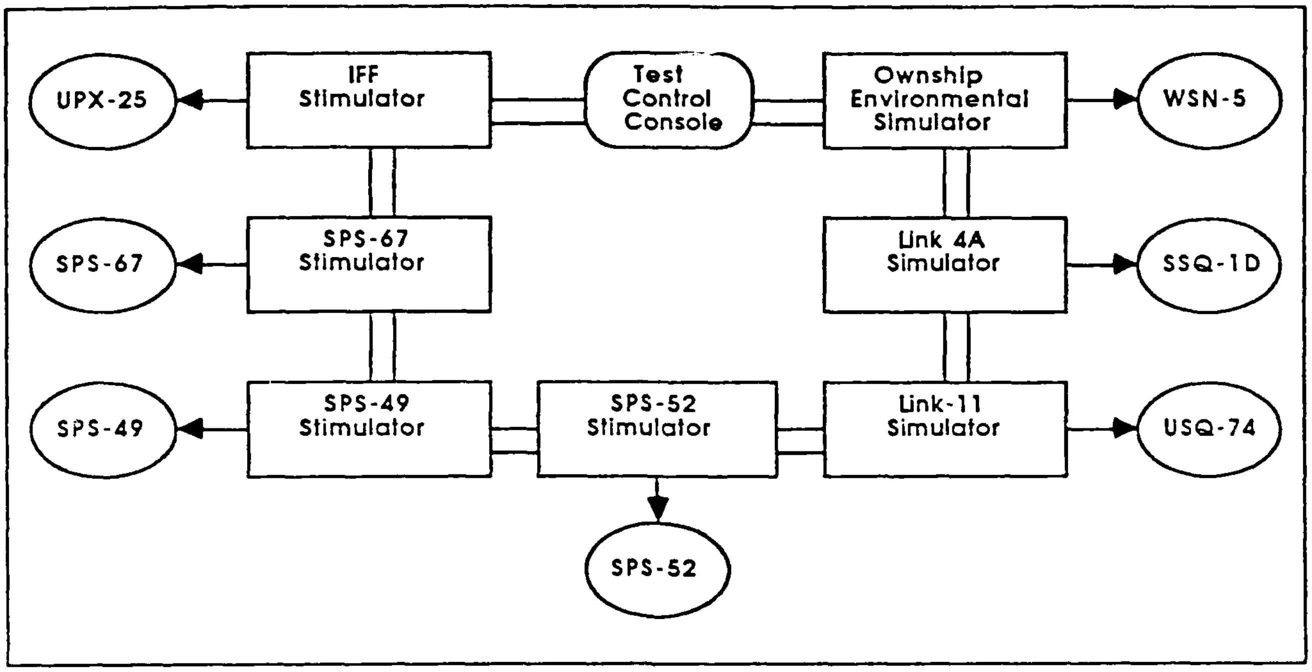

Figure 2 - LHD-1 Combat Simulation Test System Architecture

An underlying requirement for improved continuity of operation of shipboard engineering systems will be the ability to monitor the sub-systems exemplified in Figure 3. Built-in-test (BIT) and built-in-test-equipment (BITE) in the individual sub-systems are in many cases already very close to being the "stimulator" in the Integrated Test, Training, and Performance Assessment concept.

SURVEILLANCE

Surveillance or monitoring is needed to provide continuous and immediate information on engineering plant and component status, level of performance, and to detect equipment failures and predict impending failures so that corrective action can be taken by a supervisory control system. Concurrently, the information available on machinery components will reduce maintenance requirements by providing the capability for maintenance on demand rather than on a regular calendar schedule basis.

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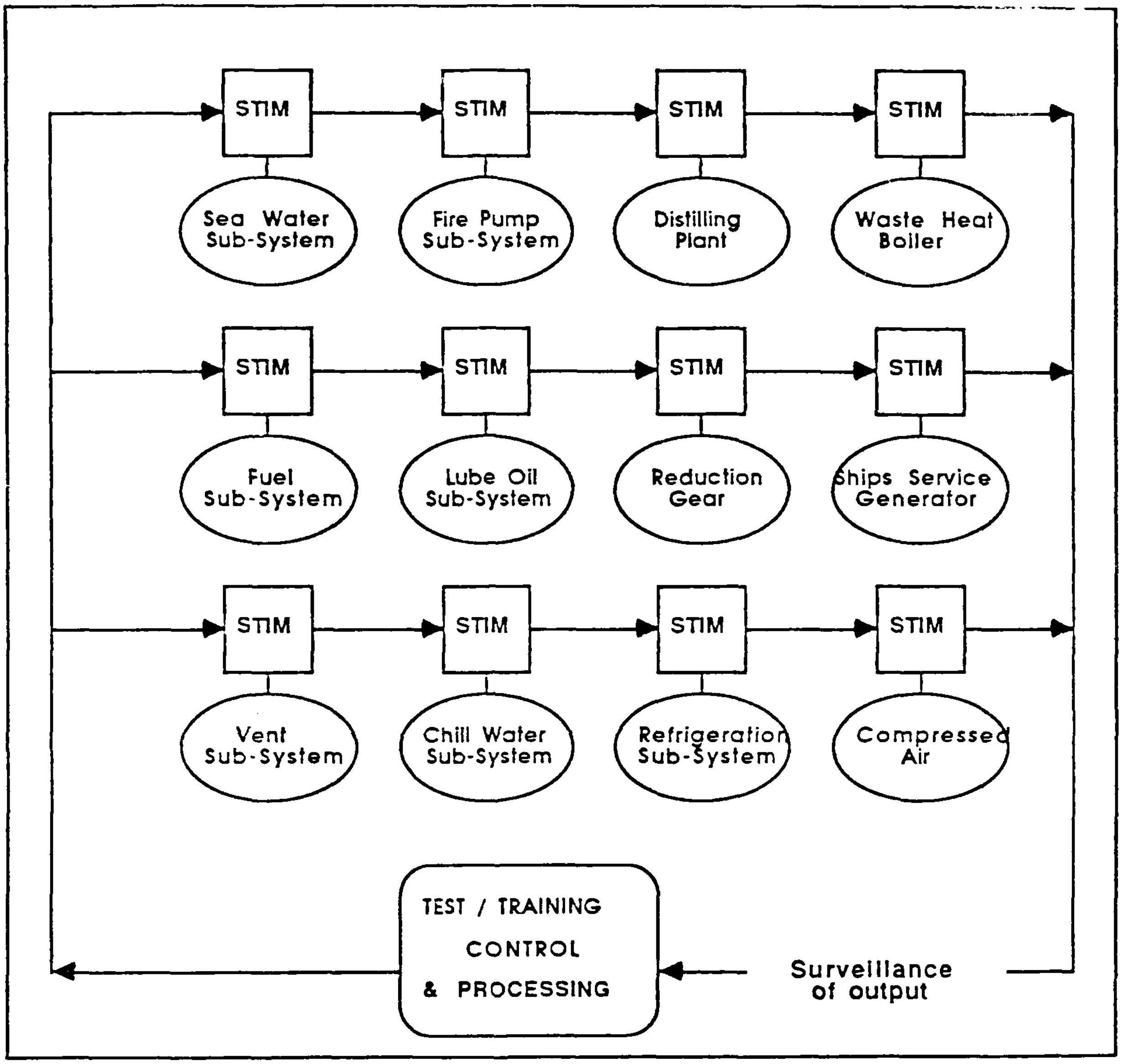

Figure 3 - Concept ITT&PA for the Engineering System

The types of input versus output measurements that ITT&PA could address in the engineering system include surveillance / monitoring of pressure, motion, flow, temperature, force, torque, and changes in the same parameters caused by operator actions.

For example, a large fraction of mechanical measurements is concerned with pressure, particularly in propulsion systems, process control systems, and ordnance systems. Pressure is the actual quantity required in many instances; however, in other cases the desired parameter is inferred from pressure measurements. Thus flow may be measured in terms of differential pressure across a deliberate flow obstruction or in terms of the force exerted against a deflection plate. In the case of motion, measurements need to be made either of the motion of objects in inertial space or of the motion of certain parts of objects with respect to other parts. The type of measurement, the amplitude and frequency response requirements, as well as certain evironmental considerations usually dictate the particular aspect of motion sensed and the type of sensor used. Motion sensors convert linear and angular displacement, and their time derivatives: velocity, accleration, and jerk, to electrical signals. Each of the motion parameters may be directly sensed and converted in one or more steps to the desired electrical signal, or the desired signal may be derived by differentiation or integration from a signal transduced from one of the related motion parameters.

Surveillance of output as compared to input leads to the performance assessment of the individual sub-systems. Controlled input via test/training controller and surveillance of the output parameters enables the system to be assessed as a whole.

CONTROL

It is desirable that the engineering system, like the combat system, be tested and the people who operate them, be trained, to provide two primary levels of information. The first level is to assess the "well being" of the equipment, computer programs, and people and inform decision makers with that information tailored to his needs. The second level is to aid in the location of failed components for the technicians.

The engineering officer of the watch is responsible for the safe and proper operation of the engineering system. In that regard ITT&PA can provide him from a distributed and continuously update data base, assigned mission responsibility as directed from the combat system, commanding officer, and/or officer of the deck. With this information the engineering officer of the watch can employ ships propulsion, electric power, auxilary systems, interior communications, etc. ITT&PA can provide him with his engineering availability, limitations, and recommended alternatives for system employment based upon its current state. ITT&PA can provide similar information to the damage control officer who has access to the data base through distributed data buses. Integrated Test, Training, and Performance Assessment can aid in fault isolation, trend analysis, and decision aids.

The combat system components, equipments, and subsystems are physically located throughout the ship, as are the components, equipments, and subsystems of the engineering system. The combat system and the engineering system, however, must merge to form an n-dimensional complex machine, the ship. Computer technology today is such that distributed processing becomes a viable solution. Effective and efficient communication

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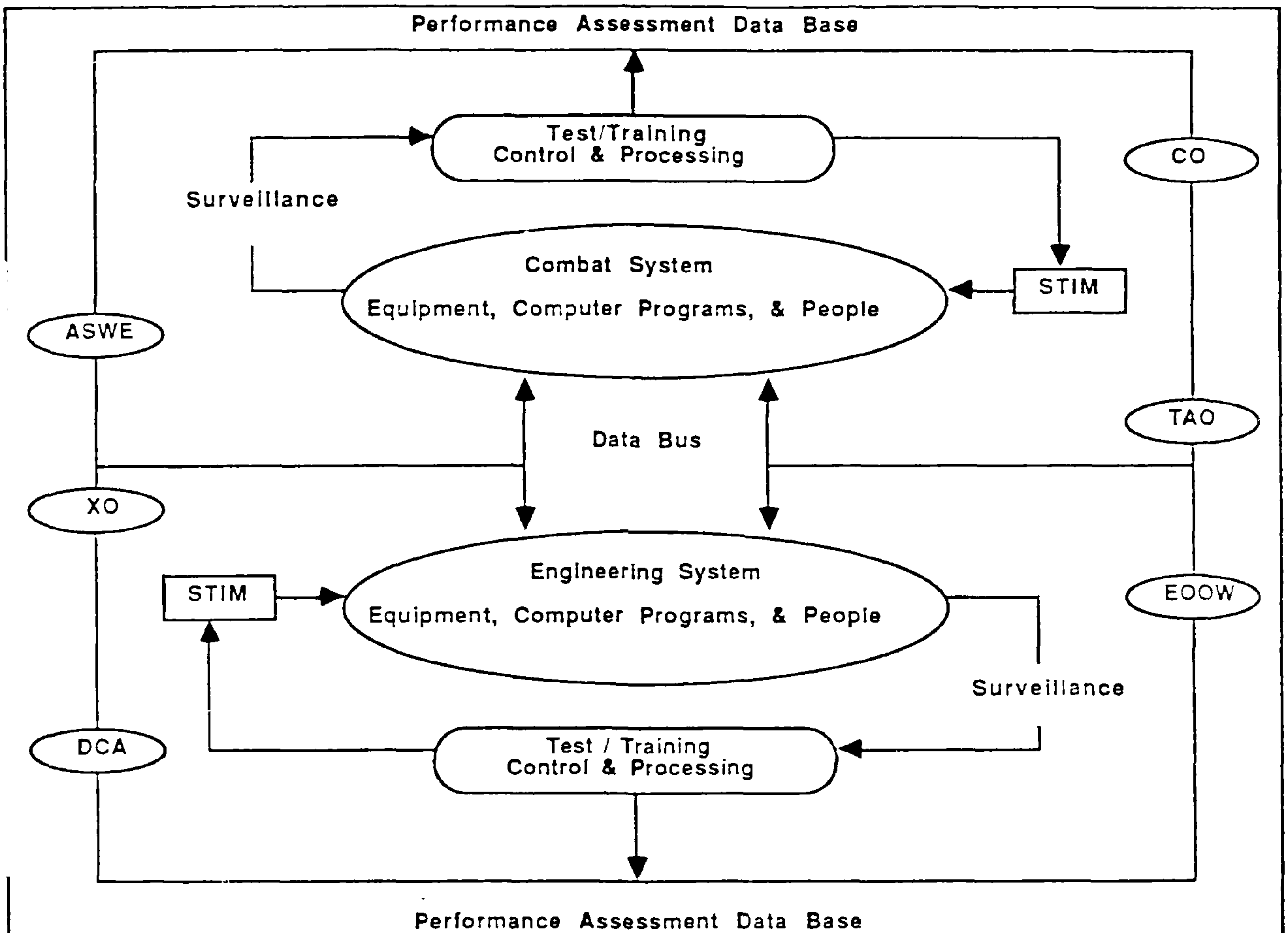
connectivity between the two major systems is required to ensure total ship control for daily operation, control for safety, and control during battle for survivability. The data buses of today provide the baseline for application of the integrated test, training, and performance assessment concept. Figure 4 represents a conceptual integrated test, training, and performance assessement architecture with distributed control workstations.



Acronym Key

ASWE = Anti-Submarine Warfare Evaluator

CO = Commanding Officer

DCA = Damage Control Assistant

EOOW = Engineering Officer of the Watch

STIM = Stimulation

TAO = Tactical Action Officer

XO = Executive Officer

Figure 4 - Integrated Test, Training, and Performance Assessment with Distributed Control and Surveillance Design

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ITT&PA OBJECTIVE

The objective of Integrated Test, Training, and Performance Assessment is to provide shipboard decision makers and maintenance personnel with a means of assessing in real time the "state of health" of the ship to optimize overall operational system performance.

PERFORMANCE

Knowledge that the system is not functioning to its maximum design capability becomes essential not only during battle but during everyday operational use for safety and efficiency. For example, what is impact on the ship if a power supply to the surveillance radar is degraded? What is the impact if the watch supervisor in fireroom number two faints due to heat exhaustion caused by inadequate air conditioning? Who will replace the tactical action officer if he is severely injured from a missile explosion? How will the electrical load be re-distributed and how fast?

The combat system operators and decision makers must know in real time the constantly changing status of the engineering system. They must know the limitations of their systems at all times in order to exploit the resultant capabilities. The propulsion system operators, technicians, and decision makers must know the ever changing combat system status in order to initiate repairs, maintenance, and shifts in load centers to exploit its maximum capability upward into the combat system. Information format and utility is different for the technicians, operators, and decision makers. The readiness status information must therefore be tailored to best support the users of the information in the shortest time possible. With the diversity of information required, the diversity of the elements, components, and sub-systems, the spacial distances between the equipments and personnel, and state of the art technology a distributed architecture is appropriate.

COST SAVINGS

While the US Navy is recognizing the need for system level testing and for system level training only recently is it beginning to recognize the overlap in test and training methodologies. From a cost standpoint, integrated test, training, and performance assessment offers an opportunity to pay only once for a more complete integrated test and training capability. This in itself is reason for integrating the closely related functions of test and training.

The efforts ongoing in combat system test / training have all been add on capabilities. Recognition of the need for system level test and training has come after the operational equipments have been funded and developed. Lessons learned indicate that had the test / training capabilities been disigned

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into the prime item equipments cost savings could have been realized not only in research and development but in life cycle logistics costs. Additionally, the add on stimulators and simulators have caused space and weight tradeoffs. The Device 20B5 for example comes in semi-truck and is therefore not an asset available at sea. Advances in today's technology in the area of very high speed integrated circuitry, local area networks, fiber optics, lap top computers all make feasible the concept of embedding the ITT&PA capabilities and techniques into prime item equipments at the design stage.

RESEARCH

The operational use of combat systems in response to stimulation and simulation resulting have resulted in lessons learned that indicate all too often it is training or the operator himself, rather than control system design that is considered at fault when the system or operators are incapable of coping with an operational situation. While research and development facilties are slowly moving forward toward discovering these lessons through experimentation, recognition that the ship must operate as one entity which includes the engineering system is significantly lacking.

Data that would be collected, processed, and distributed to the users should be maintained. The data offers insight into the availability and maintainability of the complex system as a whole. Trend analysis of the operational systems offers the opportunity to identify problem areas and feed that information back into the acquisition requirements definition process.

CONCLUSION

Increases in the performance characteristics and level of automation of surface ship systems emphasize the need for extensive and continuing training, as well as continuous and automated system performance measurement. Moreover, the complexity of current systems and lack of total system training opportunties make it imperative that operators and teams have the opportunity to train in realistic simulated environments in order to develop and maintain required performance levels.

It is also essential that commanders have an accurate and up-to-date operability status of the systems under their control. With the increasing attention paid to cost effectiveness, the high cost of dedicated training systems, and stringent limitations on inport crew availability for training, there is a critical requirement for an embedded Integrated Test, Training, and Performance Assessment capability capable of being used at sea or in port.

As the overall equipment and software requirements of training and performance assessment functions are substantially similar, significant cost savings can accrue from a combined effort.

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It is clear that further progress in Integrated Test, Training, and Performance Assessment will be closely linked to the evolution of control and surveillance system designs and their associated data buses.

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ABOUT THE AUTHORS

MR. JOHN G. KAMMERER, as the head of the Command and Control System Integration and Readiness Branch at the Naval Ocean Systems Center, San Diego, California is the technical supervisor of ongoing work in the areas of warfare systems architecture and engineering, advanced combat direction systems, AEGIS readiness, and battle force training. He is a graduate of the University of Florida and the University of Pennsylvania with a Bachelor and Masters degree in electrical engineering. He was formerly a radar systems engineer with RCA and a member of the technical staffs at Applied Physics Laboratory / John Hopkins University and Computer Sciences Corporation.

MR DAVID W. GEER is a Project Engineer with Martin Marietta Baltimore Aerospace. He is currently working on the Vertical Launch program. He is a graduate of the US Naval Academy and the Naval Post Graduate School with degrees in Marine Engineering and Operations Research. He was formerly a Control System Design Engineer with United Technologies (Norden Service Company) for five years after having spent twenty years on active duty with the US Navy.

MR. THOMAS R. TIERNAN is a scientist with the Naval Ocean Systems Center in the Command and Control System Integration and Readiness Branch. He a the project engineer with the battle force inport training program. He holds a Bachelors degree in Industrial Engineering from Purdue University and a Masters degree in Business Administration from San Diego State University. He was an active duty US Navy officer for five and a half years and worked in industry for two years.

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